Afternoon Session

(THIRD PAPER)

When the meeting resumed its sitting after lunch the CHAIRMAN, introducing the next speaker, said Lieut -Col F L HODGESS has been associated with rotating wing development over a period of some 25 years With the Cierva Co he was responsible for the mechanical design of the early Cierva Autogiros ranging from the C 17 to the C 30 , later he became Assistant Chief Designer in the Autogiro Department of G & J Weir After the war, he joined the Fairey Aviation Co and he now serves with that Company as Development Engineer

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Jet-Propelled Rotor-Blade Construction

By F L HODGESS

In presenting this paper an attempt has been made to outline some of the additional problems which are connected with the design and construction of rotor blades driven by jets at the tips

The complications which arise when ram or pulse jets are fitted are not discussed in detail as it is considered that these problems are also included among those which occur when pressure jets are used as the means of propulsion

This short paper will therefore be confined to a discussion on the engineering of rotor blades driven by pressure jets at the tips

DESIGN REQUIREMENTS

(1) In addition to the normal loads the spar or main strength member must be capable of taking the additional centrifugal force due to the concentrated weight of the jet at the tip This requirement is, of course, common to any type of jet fitted and the additional load due to C F may be many hundreds of times the weight of the unit Again due to the mass of the jet the blade is subjected to a greater bending moment on the ground

(2) Large quantities of compressed air have to be conducted through the blade from root to tip as smoothly as possible in order to cut down losses due to skin friction Generally speaking this requirement will govern the cross-sectional area of the spar tube if this member is used for piping the air , studies have shown that additional air conduits complicate the design by upsetting the transverse weight distribution, and trouble will also be encountered due to unequal longitudinal expansion both mechanical and thermal

(3) Although the internal air pressures considered at the present time are not high, of the order of three to five atmospheres, yet the bending moments generated by the hoop stresses in a conduit of anything but a pure circular cross-section can be quite high and this fact alone may have a considerable influence on the final design of the blade

(4) Another feature in the design which requires careful consideration is the differential thermal expansion between spar and skin

The temperature of the air leaving the compressor being of the order of 200°C or more and the temperature of the skin initially well below zero, under these conditions there may be nearly 1′ difference between the length of the spar and the length of the skin in a 40 ft blade and, even after thermal conditions are stabilised, there will still be a measurable difference To this must also be added the difference arising from strain between spar and skin If a continuous skin is used, some means must be provided for differential movement, such as allowing the spar and superstructure to telescope, and such an arrangement requires the superstructure to take its own centrifugal force , this will inevitably lead to additional weight

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(5) The effect which the volume of air to be passed has on the size of the spar has already been mentioned, and this in turn may influence the design of the rotor itself As an example, if a fineness ratio of say 12% is decided upon, the chord of the blade may have to be made larger in order to accommodate the air duct This will in turn increase the solidity of the rotor Alternatively the designer may consider thickening the blade or making a compromise between fineness ratio and chord

(6) The materials to be used in the construction of a pressure-jet driven rotor blade must be chosen with care, and for many reasons an all-metal blade is indicated

(7) Provision has also to be made for fuel supply to the jet and a high tension lead for ignition purposes, a requirement common to all types of blade-tip jets

(8) Normal protective treatments, particularly for light alloys, are not efficient at the temperatures encountered inside the blade, and an effective anti-corrosion paint must be hard, yet resilient at these temperatures

Construction

Having discussed some of the major design problems, a proposed construction will now be described which endeavours to satisfy these rather novel requirements

After many investigations an all-steel blade appeared to offer the best solution, and, with the exception of the spar tube which is of a high tensile nickel-chrome steel, and the trailing edge blocks which are of aluminium, the remainder of the blade is made from stainless steel

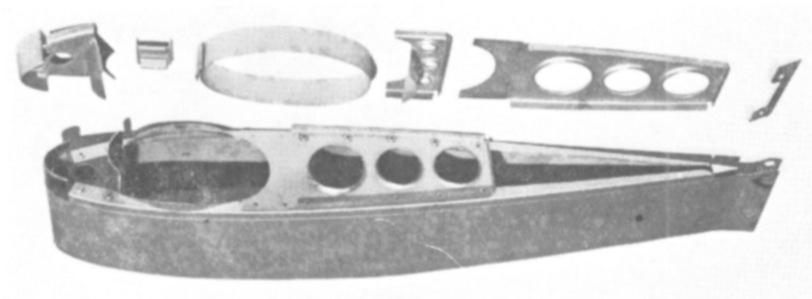

Fig 1

Before the decision was reached to use an oval steel tube as the main strength member, a number of designs were studied which embodied either aluminium alloy extrusion, or spars machined from the solid and even fabricated spars, in both steel and duralumin In some cases these were in the form of nose spars which certainly help in obtaining the correct transverse c g position

There are, however, two major criticisms of both aluminium alloy and fabricated spars

(i) sensitivity to fatigue and (ii) complication with regard to root attachments, particularly if the spars are used as air conduits

There is a third criticism of nose spars, namely lack of torsional rigidity compared with a spar of the same weight but of deeper and more nearly round section

In the present construction the spar tube is similar in manufacture to tubes previously used in helicopters and autogiros , at the root it is round with a collar which is formed integrally with the tube

This collar takes the whole of the C F and thus eliminates the necessity for drilling From a round section the tube is deformed into an oval with a ratio of major to minor axis of 1 56 to 1 Above this ratio the stress due to internal air pressure quickly rises to unacceptable values, in other words if a flatter oval of the same cross sectional area were used in order to reduce the T/C ratio of the blade, the wall thickness and hence the weight of the tube would have to be increased A short film will be shown after this paper showing how tapered tubes of varying wall thickness are manufactured

A feature of this blade construction is in the superstructure which is built up from a large number of very narrow elements, each element being threaded over the spar and clipped in place by means of a special wedge clip (See Fig 1)

A single element consists of the skin with integral flanges, nose rib, rear rib, shear web and trailing edge block , these items are secured to the spar by means of the strap and wedge clip (See Fig 2)

The skin of each element is formed from a narrow strip of very thin stainless steel (34G = 010″) which is joggled and flanged along one edge The opposite edge is open and is a tight fit over the joggled portion of the adjacent element, roughly similar to the fitting of the lid of a tin box The joggles are rolled into the strip and the flanges and contour of each strip formed in a press—thus all elements are identical in form

The nose rib, rear rib and shear web are also pressings, although the nose rib may eventually be made from a precision casting , all these items are made from different gauges of stainless steel The strap and wedge clip are pressed also from the same material

Each element is assembled on the bench, the nose rib, shear web and trailing edge block being rivetted to the skin in a bench jig The rear rib is not rivetted up at this stage

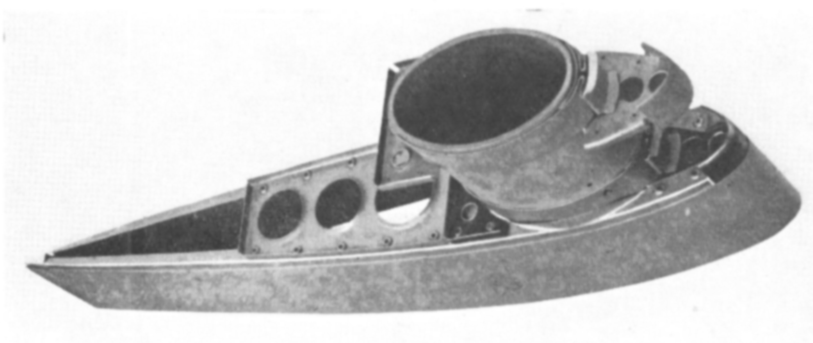

Fig 2

In building the rotor blade the elements are threaded over the spar and high tension lead simultaneously, beginning at the root of the blade and working towards the tip The rear rib is placed in position and the strap and wedge clip tightened up The flanges of the skin are then drilled through the holes in the rear rib and rivetted The leading and trailing edges of the elements are held in a jig during this operation, thus ensuring uniformity of pitch along the blade By assembling the rear rib in the final building jig, any variations in the major axis of the spar tube are accommodated

The high tension lead is also clipped to each nose rib during this operation

Finally the fuel pipe is inserted through the holes in the leading edge ribs The fuel pipe is drawn from heavy gauge stainless steel tubing and is formed with a collar at the root which enables the tube to take its own C F

The tube is supported by the holes in the leading edge ribs but is free to move longitudinally and, at the outer end, the pipe is connected to the jet by means of a high-pressure flexible hose

The problem of constructing rotor blades suitable for pressure-jet propulsion is obviously capable of more than one solution and a fairly wide choice of materials is available

The particular construction described is merely one approach to the problem, but it may be of interest to see how far the system satisfies the more important design requirements

(1) By making the main spar a tube and using it for supplying air to the jet, additional air conduits are avoided and a reasonably smooth passage is provided

NOTE —This arrangement may, under certain conditions force a compromise between chord and thickness of blade

(2) The system permits differential thermal expansion between spar, superstructure and fuel pipe

(3) Flexibility in both vertical and horizontal planes is provided, thus avoiding buckling of the underskin and trailing edges This feaure is also being incorporated in shaft-driven rotor blades In this design the oval tube provides good torsional stiffness

(4) As a result of flexibility of the superstructure, the flexural axis approximates to the spar axis and longitudinal axis of inertia, whereas with a rigid skin the flexural axis is offset and torsional loads are introduced whenever the blade bends in a vertical plane

(5) By pressing out the blade elements in a die, close conformity to the required aerofoil section is obtained

(6) Whenever the blade has to be stripped for inspection or repair the rivets can be drilled out and the same elements used for the re-build, or new elements inserted for repair

(7) Once the jigs are made the blades can be built by semi-skilled labour

(8) With the exception of the trailing edge, the skin is free from rivet heads or blemishes such as over-countersinking

(9) By making the elements of stainless steel, no protection is required except for the spar itself, and the blade can be fully ventilated

(10) Automatic de-icing is provided by the heat radiated and conducted from the spar

(11) The skin does not have to rely on bonding or rivetting to the ribs and therefore can be made of very thin steel , the construction also permits of the use of strip steel which is readily obtainable

(12) As a result of using very thin steel (in the example 010′) in narrow strips, the gap between each element will be very small, and, even under maximum thermal and stress differentials, the gap will increase by a dimension of the order of only 004″

(13) Having no external paint or fabric covering, the blade can fly through all types of weather without fear of leading edge erosion This in turn reduces the amount of maintenance required

I must thank the Fairey Aviation Company for permission to read the paper, but I should point out that the opinions expressed are my own and not necessarily those of the Company

REFERENCES

LOCKING WEDGE	PAT NO 28045/50
OVERLAPPING SECTIONS	PAT NO 21563/51

(FOURTH PAPER)

The CHAIRMAN, introducing Mr O L L FITZWILLIAMS, said Mr Fitzwilliams has had a long connection with development work dating back to his period of service with the Autogiro Department of G & J. Weir Ltd He later joined the Airborne Forces Experimental Establishment and, on leaving in 1946 to take up an appointment with the Westland Company, he was in charge of the Rotary Wing Aircraft Section Mr Fitzwilliam's work as Helicopter Engineer with the Westland Company is widely known, as are his contributions to the Association as a lecturer and Member of Council